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JAPAN'S SATELLITE DEVELOPMENT PROGRAM REVISITED

Summary

The Bush administration's May 1989 decision to go after Tokyo's satellite procurement policy under the Super 301 provision of the 1988 trade act caught many analysts off guard. True, the de facto ban on public-sector purchases of foreign spacecraft made satellites an obvious candidate. These observers figured, however, that a combination of factors, including the opening of the domestic satellite communications services market to two businesses using American-made equipment, would keep satellites off the final list of priority Japanese trade practices. What they overlooked was the concern among U.S. trade policymakers that Japan is using a protected government market to develop a commercial satellite industry.

Government and industry officials in Japan deny that the country's satellite development program is commercially oriented. But their disclaimers -- which cover work on communications satellites, the area of greatest concern in Washington -- have fallen on deaf ears. Questions about the ability of Japanese companies to bridge a significant technology gap in communications satellites also do not appear to faze American officials convinced that Tokyo's development strategy will enable Japanese competitors to challenge U.S. leadership in yet another industry. Perhaps the only way Tokyo can appease American critics is to abandon plans, now in the formative stage, to design and build a new generation of communications satellites for launch around 1995.

New Challenge to Japan's Satellite Program

Supercomputers and wood, two of the products cited by the Bush administration when it singled out Japan under the Super 301 provision of the 1988 Omnibus Trade and Competitiveness Act, were odds-on favorites in the Washington trade community for priority designation (see JEI Report No. 17A, April 28, 1989). To the surprise of many analysts, however, the White House's list of negotiating targets also included a long shot, satellites and the prohibition on the procurement of foreign spacecraft by Japanese government agencies.

The Japanese government's exclusionary purchasing regulations for satellites -- whether communications, broadcast, weather or earth observation -- unquestionably passed the statutory trade barrier test, but it was not clear that satellites met Super 301's export potential criteria since Tokyo's spacecraft requirements, restricted to nonmilitary uses, are limited. Administration watchers also doubted that the White House would go after Japan's de facto ban on public-sector procurement of foreign satellites without the active backing of U.S. satellite builders. Odds makers wondered as well whether the United States was willing to tackle Tokyo's satellite policies when it is counting on Japanese support, both financial and technical, for the manned space station program and other space projects of mutual benefit and on data from Japanese remote-sensing satellites.

What really made satellites a long shot Super 301 choice for most analysts, however, was the end to Tokyo's prohibition on sales of foreign satellites to Japan's private sector. After the domestic telecommunications market was deregulated in April 1985, the Ministry of Posts and Telecommunications licensed two joint ventures to provide commercial satellite communications services. Both companies -- Japan Communications Satellite Co., Inc., a partnership of C. Itoh & Co., Ltd. (40 percent), Mitsui & Co., Ltd. (30 percent) and Hughes Communications Inc. (30 percent), and Space Communications Corp., a Mitsubishi Group venture led by Mitsubishi Corp. (26.05 percent) and Mitsubishi Electric Corp. (20.45 percent) -- contracted for American-built spacecraft and foreign launch services. JCSAT 1, a Hughes Aircraft Co. HS-393 satellite, was launched in March 1989; the identical JCSAT 2 currently is expected to go up in early December. One of SCC's pair of satellites, Superbirds manufactured by Ford Aerospace Corp., was launched last June; its twin was set for a December launch but that date was postponed recently.

To many observers the sale of four American satellites to private Japanese operators was reason enough to leave this product off the final Super 301 list, but the arrival of commercial satellite communications services in Japan seemed to offer another reason not to make satellites a negotiating priority. In February 1989 Nippon Telegraph and Telephone Corp., potentially the biggest satellite customer in Japan, contracted to lease 13 of the 64 transponders (a satellite's receive-retransmit link) available on the two JCSAT satellites. The company, which until now has had to share space on a small, domestically built communications satellite with government agencies and private users, also has agreed to lease Superbird transponders. These moves, analysts thought, at least indirectly undermined a key part of Washington's complaint about Japan's

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public-sector satellite procurement policy -- that NTT, although privatized in April 1985, is not free to buy foreign spacecraft until the government becomes a minority stockholder in 1991 or 1992.

U.S. trade policymakers no doubt weighed these arguments in deciding whether to target satellites under Super 301. In the end the case against priority designation was no match for Washington's broader concerns about the thrust of Tokyo's policy for communications and other types of applications satellites. Like their Reagan administration counterparts, who challenged Japan's satellite procurement practices in 1983 and 1984, current officials in the Department of Commerce and the Office of the U.S. Trade Representative look at the trappings of Japan's satellite policy and see a clear-cut government effort to nurture a domestic satellite industry. For them the signs of industrial targeting are everywhere: prohibition on sales of foreign satellites to public-sector organizations, government funding for industry's research and development work, corporate collaboration on satellite projects, the required selection of Japanese manufacturers as prime contractors and the substitution of local for foreign content in Japan's satellites. From this perspective the Super 301 mechanism offered Washington a unique opportunity to head off the emergence of a rival to the U.S. satellite industry, the world leader in spacecraft hardware and software.

The Japanese government has no real quarrel with Washington's description of the direction of Tokyo's satellite policy. Development of independent technological capabilities in spacecraft design and production was implicit in the government's first statement of space policy, issued in March 1978. This theme also ran through a February 1984 policy update and the June 1989 revision of the Fundamental Guidelines of Space Policy. Government representatives, however, take strong exception to the argument that the goal of autonomous development is motivated by a commercial rationale. Japan must have an independent foundation in space technologies if it is to collaborate with the United States and other countries on the manned space station and related space research, they maintain. And the only way Japan can gain the necessary technical expertise is through a national space development program.

Buttressing their statement that Tokyo's satellite policy is not commercially driven, officials point to the lead that American companies have in spacecraft technologies and the limited financing available in Japan for technical development. At Y155 billion ($1.1 billion at Y140=$1.00) in FY 1989, projected Japanese government funding of space activities is a fraction of U.S. spending, which amounted to roughly $25 billion in FY 1988 for both civilian and military programs or close to $10 billion excluding the Department of Defense's space budget. Moreover, Japan's recent space budgets have been skewed toward funding for the next-generation H-II launch vehicle and for the space station and related space experiments at the expense, if only partial, of satellite development. Budgetary pressures, in fact, forced the government to shift the bulk of the financing responsibilities for the second- and the third-generation Japanese communications and broadcast satellites to the primary users.

This line of argument obviously has not persuaded trade officials in Washington that Japan's program is research oriented. But is the administration's skepticism justified? Does the United States have legitimate cause for

concern about the development of an internationally competitive Japanese satellite industry or are officials simply extrapolating from Japan's success in other high technology fields and assuming that satellite manufacturers will duplicate those achievements?

Japan's three satellite builders unquestionably have made considerable technical headway in the 1980s, but their current systems are not state of the art, particularly the communications satellites. Whether this gap is technological or just a function of the limited payload lift capacity of Japan's present H-I launch vehicle is not clear. That uncertainty should be eliminated when the H-II launch vehicle goes into operation, now expected to be 1994 at the earliest. But even if Japan's industry proves capable of incorporating world-class technology in its satellites, there is no guarantee that the spacecraft will be cost-competitive since satellite manufacturers do not have the big domestic market that helped companies in other industries become international competitors.

Trying to Catch Up

Responsibility for space development work in Japan is divided between two primary organizations. The Ministry of Education's Institute of Space and Astronautical Science is in charge of activities in the scientific field, including the development of scientific satellites and the vehicles to launch them. Its spacecraft are built by NEC Corp. and sent into orbit aboard launch vehicles manufactured by Nissan Motor Co., Ltd. from the ISAS Kagoshima Space Center on the southern tip of Kyushu.

R&D work on communications, broadcast, weather and earth observation satellites is coordinated by the National Space Development Agency. This organization, which falls primarily under the jurisdiction of the Science and Technology Agency, also oversees development of launch vehicles for applications satellites and conducts launches from its Tanegashima Space Center on the small southern island of the same name. Prime contractors for NASDA spacecraft are Mitsubishi Electric (communications satellites and the next-generation earth observation satellite), NEC (all weather satellites, the current pair of earth observation satellites and the next-generation broadcast satellite) and Toshiba Corp. (the first two series of broadcast satellites and the next test satellite). Mitsubishi Heavy Industries, Ltd. is responsible for vehicle integration of NASDA's rockets, now in the third generation.

Since Japan's first satellite was sent into orbit in 1970 NASDA and ISAS have launched 43 spacecraft, 39 of them successfully (see Appendices 1 and 2). ISAS has put up 18 scientific satellites whose payloads have evolved from relatively simple ones to sophisticated systems. In the process the institute's three-stage M rocket, now in the fifth generation, has established a track record as a low-cost, reliable vehicle for launching up to 770-kilogram scientific payloads into low earth orbit. In the applications area NASDA's 21 successfully orbited satellites (which include three launched by the United States) also have been marked by steady technological advancement. The same is true of its series of three-stage launch vehicles, with the current H-I capable of lifting 550-kg payloads into hard-to-achieve geostationary orbit.

This technological progress in scientific and applications satellites and launch vehicles has been the product of two different blueprints. From the

start ISAS went the independent technology development route. NASDA, in contrast, adopted a development strategy that has proved highly efficient in a number of other Japanese industries. It involved teaming up Japanese manufacturers with more experienced American aerospace companies to acquire technologies that otherwise would be too expensive and time-consuming for domestic industry to develop from scratch -- a process facilitated by the technology transfer provisions of the 1969 U.S.-Japan space cooperation agreement. At the same time NASDA funded R&D work in areas where Japanese firms already had a technical foundation, especially in electronics fields.

Measured solely by the high domestic content of Japan's current or next series of communications, broadcast and earth observation satellites, NASDA's parallel development strategy has worked. But this method of playing catch-up has had a number of drawbacks. For one, continued dependence on American technology for critical subsystems or parts has caused difficulties when NASDA satellites experience operational problems because Japanese engineers do not have access to the malfunctioning foreign parts. Perhaps more important in the Super 301 context, NASDA's drive to replace imported expertise with domestically developed technology generally has meant technically dated equipment that is more expensive to boot than satellites purchased off-the-shelf from U.S. manufacturers. That certainly is true for the country's communications satellites.

Communications Satellites - Japan's first two communications satellites intended for operational service were launched in 1983. The CS-2 spacecraft were built by the Mitsubishi Electric-Ford Aerospace team, the same companies responsible for the experimental CS satellite launched in 1977. The CS-2 and CS shared a common, FAC-supplied basic design. This design, however, was modified by the partners to reflect some of the advances in satellite technology since the CS was planned and to incorporate special features sought by NTT, which covered 60 percent of program costs.

Even with these changes, the CS-2 satellites were far less sophisticated in terms of capacity and variety of services than the communications satellites then in use in the United States and Europe. And they cost more -- about Y49.2 billion ($351.4 million), including launch, tracking and control expenses. To some extent, however, the cost differential was an inevitable by-product of NTT's goal of developing the world's first satellites to use the high-capacity 30/20-gigahertz (Ka) frequency band instead of the 14/11-Ghz (Ku) band used by the United States and Europe for communications satellites. The capacity/service gap was likewise partly intentional. The CS-2s were developed to give NTT, the National Police Agency and other public organizations telephone links between Japan's main and outlying islands and channels for nationwide emergency communications rather than to enable NTT to offer commercial voice, television and high-speed data transmission services.

In fact, capacity and cost considerations on the CS-2 project took a back seat to acquiring communications satellite product and process technologies. Given this primary objective, the program was a success. Mitsubishi Electric and its Japanese subcontractors gained some much-needed design experience working on the CS-2 spacecraft; so did NTT, which was in charge of the communications antennas and the transponders. The program also allowed Japanese companies to gain the skills to manufacture key subsystems for the communications payload since MELCO built the antennas and NEC made the transponders.

Even more valuable was the expertise Mitsubishi Electric acquired in systems integration. Ford Aerospace assembled the first CS-2 satellite at its Palo Alto, California facilities. In addition, it did the integration work, verifying all the system's interfaces, particularly the electrical connections. The U.S. subcontractor also performed the environmental tests, which establish that the satellite should survive and work under the harsh conditions to which it is likely to be exposed during launch and on station. On the second CS-2 satellite, however, prime contractor MELCO performed these three critical jobs with Ford Aerospace's assistance. This transfer of responsibility helped to raise the domestic content of the two CS-2 satellites to 38 percent compared with the 24 percent figure for the CS.

Mitsubishi Electric's work on the CS-2 series gave NASDA the confidence to make the company the prime contractor in practice as well as in name on the follow-up CS-3 communications satellites. Giving MELCO design authority in addition to AIT (assembly, integration and test) responsibility was not as risky as first might appear. From the start the space agency envisioned the project as a way for Japanese suppliers to achieve another incremental increase in satellite design and manufacturing skills, not as an effort to bridge the international technology gap in one leap. Moreover, NTT, which put up close to 70 percent of the funding for the two CS-3 satellites, was involved in the design work, and MELCO engineers were backstopped by their Ford Aerospace counterparts.

NASDA's modest program goals for the CS-3 spacecraft, launched in February and September of last year, were achieved. The communications capacity of each of the satellites was upped to 6,000 telephone circuits from 4,000 apiece on the CS-2, in part through improvements in the NEC-built transponders but mainly because each unit has more transponders -- 15 in the Ka band (including five spares) and three in the C band (one spare) versus the CS-2's six Ka-band and three C-band (one backup) transponders. Moreover, all of the transponders are operable 24 hours a day year-round. On the CS-2 only two transponders operated full-time because of the satellite's limited battery capacity, but that constraint was eliminated on the current series through the use of gallium-arsenide solar cells, a first for communications satellites. In addition, the CS-3's designed service life is seven years compared to five for its predecessor since it carries more fuel for maneuvering.

Despite these advances, the CS-3 does not stack up well against current-generation U.S.-built communications satellites -- a fact driven home when Japan's privately operated communications satellites went into service earlier this year. For example, each of the 24 primary and eight backup Ku-band transponders on JCSAT 1 can relay more than 250 full-duplex telephone circuits or transmit one high-quality television channel or a 45-megabit data stream. Superbird A, which has 10 Ka-band and 19 Ku-band transponders (including a total of seven spares), offers a similar communications capacity. Moreover, both the JCSAT and the Superbird satellites have an expected service life of 10 years.

The CS-3 also comes up short on the cost side. The pair of satellites cost approximately Y66.3 billion ($473.6 million) to build and launch. Japan Satellite Communications paid between $300 and $400 million for its two Hughes Aircraft satellites -- a figure that includes not only launch expenses but also ground tracking and control equipment, while Space Communications reportedly spent $200 million for its pair of Ford Aerospace satellites. But, as in the

case of NASDA's earlier communications satellite project, the technical advancement of Mitsubishi Electric and its Japanese subcontractors took priority over cost considerations and capacity requirements, which were limited mainly to the continuation of the CS-2's public communications services and the provision of some circuits for use by the business community. From NASDA's perspective the number that really mattered was the 80 percent domestic content of the CS-3 satellites.

Broadcast Satellites - While the development of domestic technologies was NASDA's paramount objective from the start in communications satellites, the space agency initially took a different tack in its broadcast satellite program. Swayed by the nation's public broadcasting corporation (NHK), which financed 60 percent of the Y58.3 billion ($416.4 million) cost of the BS-2 project, NASDA put state-of-the-art equipment ahead of improvements in Japanese design and manufacturing capabilities. As a result, Japan was the first country in the world with a nationwide direct broadcast satellite system. But NHK's attempt to provide television service to mountainous areas and remote islands and eliminate reception problems in congested urban environments through DBS transmission proved to be an uphill, expensive battle.

Two of the three transponders on the first BS-2 failed within four months of the satellite's January 1984 launch. Those failures limited NHK to one DBS channel instead of the pair it had planned to use. They also delayed the launch of the backup BS-2 satellite until February 1986 as engineers tested the unit's modified transponders. But NHK's troubles still were not over; the second BS-2 developed problems, subsequently corrected, in its attitude control system four months after launch. The public broadcasting company, which carried no insurance on the first BS-2, finally took control of the spare BS-2 in July 1986 and started two-channel DBS service at yearend.

The BS-2 satellites, like the experimental BSE, were designed and built by General Electric Co. for prime contractor Toshiba Corp. The company and its Japanese subcontractors did only about 30 percent of the work on the two units, mainly the communications antennas and some components for other communications subsystems, with GE supplying the transponders and other critical equipment. Yet, as prime contractor, Toshiba paid the price for the BS-2's problems, losing the bidding for the follow-up DBS contract. (GE, although it would have shared the BS-3 contract award had Toshiba won it, later came out ahead in one respect. In late 1988 NHK ordered a previously built but never launched broadcast satellite from the American manufacturer to back up the BS-2b, which has experienced additional problems.)

Since NHK and a new private broadcast company are funding 65 percent of the BS-3, the public broadcasting corporation had a big say in NASDA's September 1985 decision to give the project contract to NEC. Still, the space agency's unprecedented switch of prime contractors also reflected reordered priorities for the broadcast satellite program. Boosting domestic content came before design improvements, which were limited to increasing the transmission output of the transponders, incorporating three primary and three spare transponders on each of the identical BS-3s for three-channel TV service and extending the satellite's service life from five to seven years. Given this emphasis and the need to ensure the reliability of the new spacecraft, expected to cost Y78.4 billion ($560 million) to develop and launch, NASDA felt more comfortable going

with NEC. For one thing, that company had done more work on transponders than Toshiba.

NEC teamed up with RCA Corp. (now, ironically, a GE unit) on the BS-3 project instead of long-time partner Hughes Aircraft because NASDA insists that broadcast satellite contractors use a three-axis-stabilized attitude control system rather than the less complex spin stabilization system used by Hughes. RCA helped NEC with the BS-3's basic design and is supplying the spacecraft's service module, which provides essential support functions. NEC, however, is in charge of the communications module and is doing the AIT work on both satellites, scheduled for launch in the summer of 1990 and a year later. Its responsibilities largely account for the estimated 80 percent-plus Japanese content of the BS-3 spacecraft, but the first made-in-Japan apogee kick motor (used to move a satellite from an elliptical orbit after launch to a drift orbit and finally to its stationary orbit) also will help.

Weather Satellites - Japan's weather satellites illustrate the flexibility inherent in NASDA's parallel development strategy. The NEC-Hughes Aircraft team has turned out four generations of geostationary meteorological satellites and started work this year on the fifth, currently scheduled for launch in early 1994. The domestic content of GMS-5, however, will be no higher than the 32 percent figure for the recently launched GMS-4, which, in turn, was similar to NEC's contribution to GMS-3 and GMS-2; Hughes once again will have design and AIT authority, and prime contractor NEC will remain responsible for parts of the communications and the sensing payloads. This static division of labor has nothing to do with NEC's capabilities in the satellite field. Instead, it reflects NASDA's repeated decision to put service before experience.

The same low-risk logic also has dictated the space agency's incremental approach to GMS technical advancement. For example, the main difference between the next weather satellite and the current one is that GMS-5 will carry more sensors. That could change in the future, however, if the Ministry of Transportation, which operates the country's weather satellites through its affiliated Japan Meteorological Agency, goes ahead with its current plan to make the GMS spacecraft multipurpose satellites with locational measurement and communications services functions. As the first step in this direction, GMS-5 will have signal relay equipment for search and rescue operations.

Earth Observation Satellites - NASDA's remote-sensing satellite program is the end product of its parallel development strategy, a chance for Japanese manufacturers to develop advanced spacecraft using their own technology. MOS-1, a Y56 billion ($400 million) earth observation satellite launched in February 1987, and its twin, set to go up in February 1990, were designed, assembled, integrated and tested by prime contractor NEC. Moreover, its Japanese subcontractors, with some software technical support from foreign firms, developed and made the major subsystems, including the three-axis attitude control unit and the data collection platform transponder. They also were responsible for MOS's trio of high technology radiometers for marine, land and atmospheric observation.

With the MOS-1 project under their belts, Japan's three satellite manufacturers now are trying to establish a new state of the art for earth observation satellites. ERS-1, under development since 1986, will be equipped with

synthetic aperture radar and optical sensors to make extremely detailed geological and topographical surveys of the earth's surface. The SAR system, being developed by prime contractor Mitsubishi Electric, represents the cutting edge of satellite remote-sensing technology, capable of providing high-resolution, high-contrast observation 24 hours a day in all kinds of weather. The optical sensors are an equally ambitious undertaking. Their cost alone is expected to account for Y20 billion ($142.9 million) of the ERS-1's projected Y70 billion ($500 million) price tag. In addition, optical sensor development problems already have forced a one-year delay in ERS-1's launch to 1992.

Tough Choices for Tokyo

Ironically, world commercial satellite demand is strongest year-in, year-out in the market segment where Japanese industry now has perhaps the biggest technical and cost handicaps -- communications satellites -- and weakest in the area of potentially its greatest competitiveness -- earth observation satellites. Not surprisingly, American manufacturers have the largest lead in communications satellites and possibly the smallest in earth observation satellites. This mismatch aside and notwithstanding Commerce and USTR statements that Tokyo must abandon its satellite development program across the board to avoid retaliation, resolution of the Super 301 complaint will come down to changes in Japan's communications satellite policies and practices.

Japan's options in this area are limited. The obvious concession -- NTT's purchase of an American satellite -- is unlikely to satisfy key U.S. trade policymakers since this move would not address American worries about Japanese industrial targeting. But even if this alternative were acceptable to the Bush administration, NTT would have trouble justifying it financially.

The communications giant apparently looked into the possibility of buying a U.S. satellite after it was privatized and decided that over the medium run the Japanese market could not profitably support a NTT-operated commercial satellite communications business in addition to the competing services offered by Japan Satellite Communications and Space Communications. The country's geographical compactness and the availability of alternative ground-based systems for transmitting voice, video and data (NTT's integrated services digital network, for example) capped Japanese requirements for satellite communications services far below demand in countries like the United States, in-house analysts concluded. The Ministry of Posts and Telecommunications came to a similar conclusion in early 1986 after surveying potential users about their transponder needs through the year 2000 and, as a result, shelved an application from a third private satellite operator.

Tokyo's only other choice is to abandon plans for a follow-up to the CS-3 project. That option, while certainly unpalatable, might not be as difficult for Japan to swallow as first appears. No money has yet been budgeted for the CS-4 satellites, envisioned as state of the art for the mid-1990s, although experts said basic design work had to begin at the latest during the current fiscal year if the spacecraft are to be ready by 1995. Perhaps the main reason for the delay is that government agencies, users and manufacturers cannot figure out the financing for the project, which could cost anywhere from Y100 billion ($714.3 million) to Y150 billion ($1.1 billion).

NTT seems to have little interest in the CS-4 and certainly is not willing to foot most of the bill. It spent close to Y77 billion ($550 million) on

the development of the CS-2 and CS-3 satellites. Moreover, it apparently has lined up enough capacity on the JCSATs and the Superbirds to cover its satellite transmission requirements through the end of the 1990s. NASDA, which has asked for Y2.6 billion ($18.3 million) in the FY 1990 budget to start basic design work, cannot underwrite the entire project without scrapping another major program. Even covering 30 percent of the costs, as on the CS-3, would strain the space agency's ability to fully fund projects now under way. Moreover, neither the Ministry of Posts and Telecommunications, perhaps the CS-4's biggest government supporter, nor the Ministry of International Trade and Industry, which appears ambivalent about the project, is likely to drain money from non-space to finance the next-generation communications satellite.

Communications satellite prime contractor Mitsubishi Electric presumably is unwilling to finance a major share of the CS-4, even if the alternative is the loss of this business; the risks simply are too great. Passing on the program would not shut MELCO out of the satellite market since the company, along with Aerospatiale S.A. of France and West Germany's Messerschmitt-Bolkow-Blohm, is part of a Ford Aerospace-led satellite consortium. In any case, the United States is unlikely to demand that Japan also give up its current ETS-VI engineering test satellite project, a six-year, Y40 billion ($285.7 million) effort to develop, test and verify hardware for next-generation communications/broadcast satellites in the 2,000-kg class. This program, led by Toshiba but actively involving MELCO as well as NEC, should enable all three Japanese satellite makers to hone their design and manufacturing skills.

For further information, contact Susan MacKnight.

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The views expressed in this report are those of the author and do not necessarily represent those of the Japan Economic Institute.

Appendix 1: Japan's Applications Satellites

Name	Mission Objectives	Weight	Orbit	Launch Date	Launch Vehicle	Remarks
Communications Satellites						
Medium-Capacity Communications Satellite for Experimental Purposes (CS/Sakura)	Experiments with satellite communications systems using quasi-millimeter waves and developing techniques for operating satellite communications systems.	350 kg	Geostationary	December 1977	Thor-Delta (NASA)	Prime contractor MELCO but designed and built by FAC.
Experimental Communications Satellite (ECS/Ayame)	Development of launching, tracking/control and attitude control technologies for communications satellites as well as millimeter-wave experiments.	130 kg	Geostationary	February 1979	N-I-5	Prime contractor MELCO but designed and built by FAC. Failed to achieve planned orbit.
Experimental Communications Satellite-2 (ECS-b/Ayame-2)	Same as ECS/Ayame.	130 kg	Geostationary	February 1980	N-I-6	Prime contractor MELCO but designed and built by FAC. Failed to achieve planned orbit.
Communications Satellite-2a (CS-2a/Sakura-2a)	Provide public communications services to remote islands and maintain communications during national disasters and other emergencies as well as develop satellite communications technology.	350 kg	Geostationary	February 1983	N-II-3	Prime contractor MELCO but designed and built by FAC. Designed service life reached.
Communications Satellite-2b (CS-2b/Sakura-2b)	Same as Cs-2a/Sakura-2.	350 kg	Geostationary	August 1983	N-II-4	Designed by FAC but prime contractor MELCO did assembly, integration work and environmental testing. In-orbit spare. Designed service life reached.
Communications Satellite-3a (CS-3a)	Expand communications services provided by CS-2, including limited use by business, and advance technology for communications satellites.	550 kg	Geostationary	February 1988	H-I-3	Designed and built by prime contractor MELCO. Designed service life seven years.
Communications Satellite-3b (CS-3b)	Same as CS-3a.	550 kg	Geostationary	September 1988	H-I-4	Designed and built by prime contractor MELCO. Designed service life seven years. In-orbit spare.
Broadcast Satellites						
Medium-Scale Broadcasting Satellite for Experimental Purposes (BSE/Yuri)	Image and audio transmission tests by satellite and development of techniques for operating satellite broadcasting systems.	350 kg	Geostationary	April 1978	Thor-Delta (NASA)	Prime contractor Toshiba but designed and built by GE.

Name	Mission Objectives	Weight	Orbit	Launch Date	Launch Vehicle	Remarks
Broadcasting Satellite-2a (BS-2a/Yuri-2a)	Eliminate poor television reception in mountainous areas, outlying islands and urban environments with tall buildings and develop satellite broadcast technology, including direct broadcast satellite service.	350 kg	Geostationary	January 1984	N-II-5	Prime contractor Toshiba but designed and built by GE. Designed service life five years but both of primary transponders failed within few months of launch.
Broadcasting Satellite-2b (BS-2b/Yuri-2b)	Same as BS-2a.	350 kg	Geostationary	February 1986	N-II-7	Prime contractor Toshiba but designed and built by GE. Originally meant as in-orbit spare. Used for DBS service although experiencing problems.
*Broadcasting Satellite-3a (BS-3a)	Expand broadcasting services provided by BS-2 and home satellite broadcasting technology.	550 kg	Geostationary	Summer 1990	H-I-7	Prime contractor NEC but working with GE's RCA unit. Designed service life seven years.
*Broadcasting Satellite-3b (BS-3b)	Same as BS-3a, although one transponder (channel) will be used for high-definition television broadcasting.	550 kg	Geostationary	Summer 1991	H-I-8	Prime contractor NEC but working with GE's RCA unit. Designed service life seven years. In-orbit spare.
Earth Observation/ Meteorological Satellites						
Ionosphere Sounding Satellite (ISS/Ume)	Observe ionosphere to improve accuracy of forecasts and warning systems for short-wave communications.	141 kg	Circular	February 1976	N-I-2	Prime contractor MELCO. Lost contact one month after launch.
Ionosphere Sounding Satellite-2 (ISS-b/Ume-2)	Same as ISS/Ume.	141 kg	Circular	February 1978	N-I-4	Prime contractor MELCO. Mission completed February 1983.
Geostationary Meteorological Satellite (GMS/Himawari)	Participate in Global Atmosphere Research Program with objective of improving accuracy of Japanese weather forecasting through geostationary satellite observation of cloud formations.	303 kg	Geostationary	July 1977	Thor-Delta (NASA)	Prime contractor NEC but designed and built by Hughes. Designed service life three years but operated until June 1984.
Geostationary Meteorological Satellite-2 (GMS-2/Himawari-2)	Improve meteorological service in Japan and develop meteorological satellite technology.	296 kg	Geostationary	August 1981	N-II-2	Prime contractor NEC but designed and built by Hughes. Designed service life three years but decommissioned in late 1983 after problems developed.
Geostationary Meteorological Satellite-3 (GMS-3/Himawari-3)	Continued improvement of meteorological service in Japan and further development of meteorological satellite technology.	296 kg	Geostationary	August 1984	N-II-6	Prime contractor NEC but designed and built by Hughes. Designed service life five years.

Name	Mission Objectives	Weight	Orbit	Launch Date	Launch Vehicle	Remarks
Geostationary Meteorological Satellite-4 (GMS-4/Himawari-4)	Continued improvement of meteorological service in Japan and further development of meteorological satellite technology.	345 kg	Geostationary	September 1989	H-I-5	Prime contractor NEC but designed and built by Hughes. Designed service life five years. Will take over for GMS-3 in December.
*Geostationary Meteorological Satellite-5 (GMS-5)	Continued improvement of meteorological service in Japan and further development of meteorological satellite technology. Will also be used for search and rescue operations.	n.a.	Geostationary	Early 1994 (planned)	H-II-4	Prime contractor NEC but will be designed and built by Hughes. Expected service life five years. Development work started in FY 1989.
Experimental Geodetic Payload (EGP)	Improve accuracy of geodetic surveys by using satellites.	685 kg	Circular	August 1986	H-I-1 (two-stage test flight)	Prime contractor KHI. Designed service life five years.
Marine Observation Satellite-1 (MOS-1/Momo-1)	Observe marine phenomena, especially colors and surface temperature of sea and establish technologies common to earth observation satellites.	740 kg	Sun synchronous	February 1987	N-II-8 (two-stage)	Designed and built by prime contractor NEC. Designed service life two years.
*Marine Observation Satellite-1b (MOS-1b)	Same as MOS-1.	740 kg	Sun synchronous	February 1990	H-I-6 (two-stage)	Prime contractor NEC. Designed service life two years. Ready for launch.
*Earth Resources Satellite-1 (ERS-1)	Establish active observation technologies and collect information on land use, agriculture, forestry and environment in addition to coastal zone monitoring.	1,400 kg	Sun synchronous	Early 1992	H-I-9 (two-stage)	Prime contractor MELCO. Will have synthetic aperture radar so can observe earth 24 hours a day regardless of weather. Launch delayed a year because of problems in developing optical sensors. Expected service life two years.
*Advanced Earth Observation Satellite (ADEOS)	Continue and advance earth observation technologies developed in MOS and ERS programs, develop sophisticated optical sensors for earth observation, conduct experiments on earth observation data relay using data relay satellites and develop modular satellite as prototype for future space platform.	2,500 kg	Polar	FY 1994 (planned)	H-II-5	Prime contractor not yet selected. Preliminary design work started in FY 1988.
Engineering Test Satellites						
Engineering Test Satellite-I (ETS-I/Kiku)	Confirm launch technology, acquire satellite tracking and control technology, test antenna performance and examine satellite environment.	82 kg	Circular	September 1975	N-I-1	Prime contractor NEC. Mission lasted until late April 1982.

Name	Mission Objectives	Weight	Orbit	Launch Date	Launch Vehicle	Remarks
Engineering Test Satellite-II (ETS-II/Kiku-2)	Learn technologies for launching and tracking/controlling geostationary satellites and for controlling their attitude as well as carry out tests of onboard equipment.	130 kg	Geostationary	February 1977	N-I-3	Prime contractor MELCO. Mission completed in six months.
Enginering Test Satellite-III (ETS-III/Kiku-4)	Develop production and operations technologies for satellites requiring high power and test three-axis attitude control, deployable solar panels and onboard equipment.	385 kg	Circular	September 1982	N-I-7	Prime contractor Toshiba. Mission lasted one year but operations continued until early March 1985.
Engineering Test Satellite-IV (ETS-IV/Kiku-3)	Verify launch performance of N-II vehicle, acquire data on launch environment as well as technologies for producing and managing large satellites and test functions of onboard equipment.	640 kg	Highly elliptic	February 1981	N-II-1	Prime contractor MELCO. Mission completed in three months but operations continued until late December 1985.
Engineering Test Satellite-V (ETS-V/Kiku-5)	Verify launch performance of three-stage H-I vehicle, confirm performance of first geostationary three-axis-stabilized satellite bus system and first apogee kick motor developed in Japan and conduct mobile satellite communications experiments.	550 kg	Geostationary	August 1987	H-I-2 (three-stage test flight)	Prime contractor MELCO.
*Engineering Test Satellite-VI (ETS-VI)	Verify launch performance of H-II vehicle, establish bus technology for three-axis-stabilized geostationary satellite in 2,000 kg class and develop technologies for next-generation satellite communications, especially communications between satellites but also more advanced fixed and mobile satellite communications.	2,000 kg	Geostationary	Summer 1993 (planned)	H-II-2 (test flight)	Prime contractor Toshiba but MELCO and NEC each responsible for about 30 percent of the work. Expected service life 10 years. Design work under way.

*Funded as of FY 1989.

Key to company abbreviations:

KHI	Kawasaki Heavy Industries, Ltd.	FAC	Ford Aerospace Corp.
MELCO	Mitsubishi Electric Corp.	GE	General Electric Co.
NEC	NEC Corp.	Hughes	Hughes Aircraft Co.
Toshiba	Toshiba Corp.	RCA	RCA Corp. (now owned by GE)

Source: Adapted from Science and Technology Agency, Research and Development Bureau, Space in Japan 1988-89.

Appendix 2: Japan's Scientific Satellites

Name	Mission Objectives	Weight	Orbit	Launch Date	Launch Vehicle
Test Satellite (Ohsumi)	Learn satellite launch technology and perform engineering test of satellite, Japan's first spacecraft.	24 kg	Elliptic	February 1970	L-4S-5
Test Satellite (MS-T1/Tansei)	Test satellite environment and spacecraft subsystem technology.	63 kg	Circular	February 1971	M-4S-2
First Scientific Satellite (MS-F2/Shinsei)	Study ionospheric plasma, cosmic rays and solar radio emissions.	66 kg	Elliptic	September 1971	M-4S-3
Second Scientific Satellite (Rexs/Denpa)	Study ionospheric plasma.	75 kg	Elliptic	August 1972	M-4S-4
Test Satellite (MS-T2/Tansei-II)	Measure launch vehicle performance and study attitude control technology.	56 kg	Elliptic	February 1974	M-3C-1
Third Scientific Satellite (Starts/Taiyo)	Observe relationship between solar radiation and the atmosphere.	86 kg	Elliptic	February 1975	M-3C-2
Test Satellite (MS-T3/Tansei-III)	Measure launch vehicle performance and study magnetic attitude stabilization and ultra-violet photometry.	129 kg	Elliptic	February 1977	M-3H-1
Fifth Scientific Satellite (Exos-A/Kyokko)	Observe auroral phenomena.	126 kg	Elliptic	February 1978	M-3H-2
Sixth Scientific Satellite (Exos-B/Jikiken)	Observe space plasma phenomena. (Japan's first high-altitude scientific spacecraft.)	90 kg	Highly elliptic	September 1978	M-3H-3
Fourth Scientific Satellite (Corsa-b/Hakucho)	Observe X-ray bursts, X-ray stars, nova and soft X-ray sources. (First Japanese X-ray astronomy satellites.)	96 kg	Near circular	February 1979	M-3C-4
Test Satellite (MS-T4/Tansei-IV)	Measure launch vehicle performance and perform space technology tests important to precise satellite pointing. (First ISAS satellite to deploy solar panels.)	185 kg	Near circular	February 1980	M-3S-1
Seventh Scientific Satellite (Astro-A/Hinotori)	Observe two-dimensional hard X-ray image of solar flares and solar particle rays. (Japan's first solar research satellite.)	188 kg	Near circular	February 1981	M-3S-2
Eighth Scientific Satellite (Astro-B/Tenma)	Conduct two-dimensional imaging of celestial X-ray sources like X-ray nebulae and X-ray galaxies as well as observe X-ray bursts with high temporal and spectrum resolution.	180 kg	Elliptic	February 1982	M-3S-3
Ninth Scientific Satellite (Exos-C/Ohzora)	Investigate earth's upper atmosphere through extensive use of optics, including measurement of levels of ozone, carbon dioxide and sulfur dioxide in low ionosphere and levels of carbon dioxide in upper atmosphere.	210 kg	Elliptic	February 1984	M-3S-4

Name	Mission Objectives	Weight	Orbit	Launch Date	Launch Vehicle
Interplanetary Test Spacecraft (MS-TS/Sakigake)	Measure launch vehicle performance, gain interplanetary flight techniques, learn ultra-long-range communications technology and study attitude control technology on Halley's Comet probe. (Japan's first deep-space mission.)	138 kg	Heliocentric	January 1985	M-3SII-1
Tenth Scientific Satellite (Planet-A/Suisei)	Research interplanetary space plasma and obtain ultraviolet images of the coma of Halley's Comet. (Flew within 90,000 miles of the comet nucleus.)	125 kg	Heliocentric	August 1985	M-3SII-2
Eleventh Scientific Satellite (Astro-C/Ginga)	Provide quick response to X-ray events and provide high-quality spectral data on X-ray sources. (First ISAS three-axis-stabilized satellite.)	420 kg	Circular	February 1987	M-3SII-3
Twelfth Scientific Satellite (Exos-D/Akebono)	Observe auroras caused by particle acceleration in magnetosphere. (Carried eight observation and measurement devices.)	295 kg	Highly elliptic	February 1989	M-3SII-4
*Thirteenth Scientific Satellite (Muses-A)	Perform two or three lunar swing-by maneuvers, inject a small satellite into lunar orbit and continue lunar swing-by flights for a year in effort to master technology needed to send probes to Venus and Mars.	198 kg	Elliptic	February 1990	M-3SII
*Fourteenth Scientific Satellite (Solar-A)	Obtain high-quality images of solar flares during next solar maximum period. (Will carry two X-ray imaging telescopes, one operating in soft X-ray wave-lengths and the other in the hard X-ray spectrum.)	450 kg	Semi-circular	Summer 1991	M-3SII
*Fifteenth Scientific Satellite (Astro-D)	Provide high-resolution data on faint X-ray sources through use of X-ray telescope with long focal length.	n.a.	Semi-circular	February 1993	M-3SII
*Sixteenth Scientific Satellite (Muses-B)	Continue work needed to send probes to Venus and Mars.	n.a.	n.a.	February 1994	M-3SII
*Magnetic Field Observation Satellite (Geotail)	Observe structure and dynamics of magnetosphere tail that exists on nighttime side of earth.	574 kg	n.a.	FY 1992	U.S. space shuttle

*Funded as of FY 1989.

Source: Adapted from Science and Technology Agency, Research and Development Bureau, Space in Japan 1988-89.